

7. CONVERSION OF UNITS

The table below gives conversion factors from a variety of units to the corresponding SI unit. For each physical quantity the name is given, followed by the recommended symbol(s). Then the SI unit is given, followed by the esu, emu, Gaussian unit (Gau), atomic unit (au), and other units in common use, with their conversion factors to SI. The constant ζ which occurs in some of the electromagnetic conversion factors is the (exact) pure number $2.997\,924\,58 \times 10^{10} = c_0/(\text{cm s}^{-1})$.

The inclusion of non-SI units in this table should not be taken to imply that their use is to be encouraged. With some exceptions, SI units are always to be preferred to non-SI units. However, since many of the units below are to be found in the scientific literature, it is convenient to tabulate their relation to the SI.

For convenience units in the esu and Gaussian systems are quoted in terms of the four dimensions *length*, *mass*, *time*, and *electric charge*, by including the franklin (Fr) as an abbreviation for the electrostatic unit of charge and $4\pi\epsilon_0$ as a constant with dimensions $(\text{charge})^2/(\text{energy} \times \text{length})$. This gives each physical quantity the same dimensions in all systems, so that all conversion factors are pure numbers. The factors $4\pi\epsilon_0$ and the Fr may be eliminated by writing $\text{Fr} = \text{esu of charge} = \text{erg}^{1/2}\text{cm}^{1/2} = \text{cm}^{3/2}\text{g}^{1/2}\text{s}^{-1}$, $4\pi\epsilon_0 = \epsilon_0^{(\text{ir})} = 1 \text{ Fr}^2 \text{ erg}^{-1} \text{ cm}^{-1} = 1$, to recover esu expressions in terms of three base units. The symbol Fr should be regarded as a compact representation of (esu of charge).

Conversion factors are either given exactly (when the = sign is used), or they are given to the approximation that the corresponding physical constants are known (when the $\approx$ sign is used). In the latter case the uncertainty is always less than ± 5 in the last digit quoted.

Name	Symbol	Relation to SI
<i>Length, l</i>		
metre (SI unit)	m	
centimetre (cgs unit)	cm	$= 10^{-2} \text{ m}$
bohr (au)	a_0, b	$= 4\pi\epsilon_0\hbar^2/m_e e^2 \approx 5.291\,77 \times 10^{-11} \text{ m}$
ångström	Å	$= 10^{-10} \text{ m}$
micron	μ	$= \mu\text{m} = 10^{-6} \text{ m}$
x unit	X	$\approx 1.002 \times 10^{-13} \text{ m}$
fermi	f, fm	$= \text{fm} = 10^{-15} \text{ m}$
inch	in	$= 2.54 \times 10^{-2} \text{ m}$
foot	ft	$= 12 \text{ in} = 0.3048 \text{ m}$
yard	yd	$= 3 \text{ ft} = 0.9144 \text{ m}$
mile	mi	$= 1760 \text{ yd} = 1609.344 \text{ m}$
nautical mile		$= 1852 \text{ m}$
<i>Area, A</i>		
square metre (SI unit)	m^2	
barn	b	$= 10^{-28} \text{ m}^2$
acre		$\approx 4046.856 \text{ m}^2$
are	a	$= 100 \text{ m}^2$
hectare	ha	$= 10^4 \text{ m}^2$
<i>Volume, V</i>		
cubic metre (SI unit)	m^3	
litre	l, L	$= \text{dm}^3 = 10^{-3} \text{ m}^3$
lambda	λ	$= \mu\text{l} = 10^{-6} \text{ dm}^3$
barrel (US)		$\approx 158.987 \text{ dm}^3$
gallon (US)	gal (US)	$= 3.785\,41 \text{ dm}^3$
gallon (UK)	gal (UK)	$= 4.546\,09 \text{ dm}^3$

Name	Symbol	Relation to SI
<i>Mass, m</i>		
kilogram (SI unit)	kg	
gram (cgs unit)	g	$= 10^{-3} \text{ kg}$
electron mass (au)	m_e	$\approx 9.109\,39 \times 10^{-31} \text{ kg}$
unified atomic mass unit, dalton	u, Da	$= m_a(^{12}\text{C})/12 \approx 1.660\,540 \times 10^{-27} \text{ kg}$
tonne	t	$= \text{Mg} = 10^3 \text{ kg}$
pound (avoirdupois)	lb	$= 0.453\,592\,37 \text{ kg}$
ounce (avoirdupois)	oz	$\approx 28.3495 \text{ g}$
ounce (troy)	oz (troy)	$\approx 31.1035 \text{ g}$
agrain	gr	$= 64.798\,91 \text{ mg}$
<i>Time, t</i>		
second (SI, cgs unit)	s	
au of time	$\hbar/E_h$	$\approx 2.41888 \times 10^{-17} \text{ s}$
minute	min	$= 60 \text{ s}$
hour	h	$= 3600 \text{ s}$
day ^a	d	$= 86\,400 \text{ s}$
year ^b	a	$\approx 31\,556\,952 \text{ s}$
svdberg	Sv	$= 10^{-13} \text{ s}$
<i>Acceleration, a</i>		
SI unit	m s^{-2}	$= 9.806\,65 \text{ m s}^{-2}$
standard accleration of free fall	g_n	
gal, galileo	Gal	$= 10^{-2} \text{ m s}^{-2}$
<i>Force, F</i>		
newton (SI unit) ^c	N	$= \text{kg m s}^{-2}$
dyne (cgs unit)	dyn	$= \text{g cm s}^{-2} = 10^{-5} \text{ N}$
au of force	E_h/a_0	$\approx 8.238\,73 \times 10^{-8} \text{ N}$
kilogram-force	kgf	$= 9.806\,65 \text{ N}$
<i>Energy, U</i>		
joule (SI unit)	J	$= \text{kg m}^2 \text{ s}^{-2}$
erg (cgs unit)	erg	$= \text{g cm}^2 \text{ s}^{-2} = 10^{-7} \text{ J}$
hartree (au)	E_h	$= \hbar^2/m_e a_0^2 \approx 4.359\,75 \times 10^{-18} \text{ J}$
rydberg	Ry	$= E_h/2 \approx 2.179\,87 \times 10^{-18} \text{ J}$
electronvolt	eV	$= e \times \text{V} \approx 1.602\,18 \times 10^{-19} \text{ J}$
calorie, thermochemical	cal _{th}	$= 4.184 \text{ J}$
calorie, international	cal _{IT}	$= 4.1868 \text{ J}$
15°C calorie	cal ₁₅	$\approx 4.1855 \text{ J}$
litre atmosphere	1 atm	$= 101.325 \text{ J}$
British thermal unit	Btu	$= 1055.06 \text{ J}$
<i>Pressure, p</i>		
pascal (SI unit)	Pa	$= \text{N m}^{-2} = \text{kg m}^{-1} \text{ s}^{-2}$
atmosphere	atm	$= 101\,325 \text{ Pa}$
bar	bar	$= 10^5 \text{ Pa}$
torr	Torr	$= (101\,325/760) \text{ Pa} \approx 133.322 \text{ Pa}$
millimetre of mercury (conventional)	mmHg	$= 13.5951 \times 980.665 \times 10^{-2} \text{ Pa} \approx 133.322 \text{ Pa}$
pounds per square inch	psi	$\approx 6.894\,757 \times 10^3 \text{ Pa}$

Name	Symbol	Relation to SI
<i>Power, P</i>		
watt (SI unit)	W	$= \text{kg m}^2 \text{s}^{-3}$
horse power	hp	$= 745.7 \text{ W}$
<i>Action, L, J (angular momentum)</i>		
SI unit	J s	$= \text{kg m}^2 \text{s}^{-1}$
cgs unit	erg s	$= 10^{-7} \text{ J s}$
au of action	$\hbar$	$= \hbar/2\pi \approx 1.054 \times 10^{-34} \text{ J s}$
<i>Dynamic viscosity, η</i>		
SI unit	Pa s	$= \text{kg m}^{-1} \text{s}^{-1}$
poise	P	$= 10^{-1} \text{ Pa s}$
centipoise	cP	$= \text{mPa s}$
<i>Kinematic viscosity, ν</i>		
SI unit	$\text{m}^2 \text{s}^{-1}$	$= 10^{-4} \text{ m}^2 \text{s}^{-1}$
stokes	St	
<i>Thermodynamic temperature, T</i>		
kelvin (SI unit)	K	
degree Rankine ^d	°R	$= (5/9) \text{ K}$
<i>Entropy, S</i>		
<i>Heat capacity, C</i>		
SI unit	J K^{-1}	
clausius	Cl	$= \text{cal}_{\text{th}}/\text{K} = 4.184 \text{ J K}^{-1}$
<i>Molar entropy, S_{m}</i>		
<i>Molar heat capacity, C_{m}</i>		
SI unit	$\text{J K}^{-1} \text{mol}^{-1}$	
entropy unit	e.u.	$= \text{cal}_{\text{th}} \text{K}^{-1} \text{mol}^{-1} = 4.184 \text{ J K}^{-1} \text{mol}^{-1}$
<i>Molar volume, V_{m}</i>		
SI unit	$\text{m}^3 \text{mol}^{-1}$	
amagat ⁵	amagat	$= V_{\text{m}} \text{ of real gas at 1 atm and 273.15 K}$ $\approx 22.4 \times 10^{-3} \text{ m}^3 \text{mol}^{-1}$
<i>Amount density, $1/V_{\text{m}}$</i>		
SI unit	mol m^{-3}	
amagat ^e	amagat	$= 1/V_{\text{m}} \text{ of a real gas at 1 atm and 273.15 K}$ $\approx 44.6 \text{ mol m}^{-3}$
<i>Plane angle, α</i>		
radian (SI unit)	rad	
degree	°	$= \text{rad} \times 2\pi/360 \approx (1/57.295\,78) \text{ rad}$
minute	'	$= \text{degree}/60$
second	"	$= \text{degree}/3600$
grade	grad	$= \text{rad} \times 2\pi/400 \approx (1/63.661\,98) \text{ rad}$

Name	Symbol	Relation to SI
<i>Radioactivity, A</i>		
becquerel (SI unit)	Bq	$= \text{s}^{-1}$
curie	Ci	$= 3.7 \times 10^{10} \text{ Bq}$
<i>Absorbed dose of radiation^f</i>		
gray (SI unit)	Gy	$= \text{J kg}^{-1}$
rad	rad	$= 0.01 \text{ Gy}$
<i>Dose equivalent</i>		
sievert (SI unit)	Sv	$= \text{J kg}^{-1}$
rem	rem	$\approx 0.01 \text{ Sv}$
<i>Electric current, I</i>		
ampere (SI unit)	A	
esu, Gau	$(10/\zeta)\text{A}$	$\approx 3.335\,64 \times 10^{-10} \text{ A}$
biot (emu)	Bi	$= 10 \text{ A}$
au	$eE_{\text{h}}/\hbar$	$\approx 6.623\,62 \times 10^{-3} \text{ A}$
<i>Electric charge, Q</i>		
coulomb (SI unit)	C	$= \text{A s}$
franklin (esu, Gau)	Fr	$= (10/\zeta)\text{C} \approx 3.335\,64 \times 10^{-10} \text{ C}$
emu (abcoulomb)		$= 10 \text{ C}$
proton charge (au)	e	$\approx 1.602\,18 \times 10^{-19} \text{ C} \approx 4.803\,21 \times 10^{-10} \text{ Fr}$
<i>Charge density, ρ</i>		
SI unit	C m^{-3}	
esu, Gau	Fr cm^{-3}	$= 10^7 \zeta^{-1} \text{C m}^{-3} \approx 3.33564 \times 10^{-4} \text{ C m}^{-3}$
au	ea_0^{-3}	$\approx 1.081\,20 \times 10^{-12} \text{ C m}^{-3}$
<i>Electric potential, V, ϕ</i>		
volt (SI unit)	V	$= \text{JC}^{-1} = \text{J A}^{-1} \text{s}^{-1}$
esu, Gau	erg Fr^{-1}	$= \text{Fr cm}^{-1}/4\pi\epsilon_0 = 299.792\,458 \text{ V}$
$\text{'cm}^{-1}\text{g}$	$e \text{ cm}^{-1}/4\pi\epsilon_0$	$\approx 1.439\,97 \times 10^{-7} \text{ V}$
au	$e/4\pi\epsilon_0 a_0$	$= E_{\text{h}}/e \approx 27.2114 \text{ V}$
mean international volt		$= 1.000\,34 \text{ V}$
US international volt		$= 1.000\,330 \text{ V}$
<i>Electric resistance, R</i>		
ohm (SI unit)	Ω	$= \text{V A}^{-1} = \text{m}^2 \text{kg s}^{-3} \text{A}^{-2}$
mean international ohm		$= 1.1000\,49 \Omega$
US international ohm		$= 1.000\,495 \Omega$
<i>Electric field, E</i>		
SI unit	V m^{-1}	$= \text{J C}^{-1} \text{m}^{-1}$
esu, Gau	$\text{Fr cm}^{-2}/4\pi\epsilon_0$	$= 2.997\,924\,58 \times 10^4 \text{ V m}^{-1}$
$\text{'cm}^{-2}\text{g}$	$e \text{ cm}^{-2}/4\pi\epsilon_0$	$\approx 1.439\,97 \times 10^{-5} \text{ V m}^{-1}$
au	$e/4\pi\epsilon_0 a_0^2$	$= 5.142\,21 \times 10^{11} \text{ V m}^{-1}$
<i>Electric field gradient, $E'_{\alpha\beta}$, $q_{\alpha\beta}$</i>		
SI unit	V m^{-2}	$= \text{J C}^{-1} \text{m}^{-2}$
esu, Gau	$\text{Fr cm}^{-3}/4\pi\epsilon_0$	$= 2.997\,924\,58 \times 10^6 \text{ V m}^{-2}$

Name	Symbol	Relation to SI
'cm ⁻³ ' _g	$e \text{ cm}^{-3}/4\pi\epsilon_0$	$\approx 1.439\,97 \times 10^{-3} \text{ V m}^{-2}$
au	$e/4\pi\epsilon_0 a_0^3$	$\approx 9.717\,36 \times 10^{21} \text{ V m}^{-2}$
<i>Electric dipole moment, p, μ</i>		
SI unit	C m	
esu, Gau	Fr cm	$\approx 3.335\,64 \times 10^{-12} \text{ C m}$
debye	D	$= 10^{-18} \text{ Fr cm} \approx 3.335\,64 \times 10^{-30} \text{ C m}$
'cm' dipole length ^g	$e \text{ cm}$	$\approx 1.602\,18 \times 10^{-21} \text{ C m}$
au	ea_0	$\approx 8.478\,36 \times 10^{-30} \text{ C m}$
<i>Electric quadrupole moment, Q_{αβ}, Θ_{αβ}, eQ</i>		
SI unit	C m ²	
esu, Gau	Fr cm ²	$\approx 3.335\,64 \times 10^{-14} \text{ C m}^{-2}$
'cm ² ', quadrupole area ^g	$e \text{ cm}^2$	$\approx 1.602\,18 \times 10^{-23} \text{ C m}^2$
au	ea_0^2	$\approx 4.486\,55 \times 10^{-40} \text{ C m}^2$
<i>Polarizability, α</i>		
SI unit	J ⁻¹ C ² m ²	= F m ²
esu, Gau, 'cm ³ '	$4\pi\epsilon_0 \text{ cm}^3$	$\approx 1.112\,65 \times 10^{-16} \text{ J}^{-1} \text{ C}^2 \text{ m}^2$
polarizability volume ^g		
'Å ³ ' _g	$4\pi\epsilon_0 \text{ Å}^3$	$\approx 1.112\,65 \times 10^{-40} \text{ J}^{-1} \text{ C}^2 \text{ m}^2$
au	$4\pi\epsilon_0 a_0^3$	$\approx 1.648\,78 \times 10^{-41} \text{ J}^{-1} \text{ C}^2 \text{ m}^2$
<i>Electric displacement, D (Volume) polarization, P</i>		
SI unit	C m ⁻²	
esu, Gau	Fr cm ⁻²	$= (10^5/9) \text{ C m}^{-2} \approx 3.33564 \times 10^{-6} \text{ C m}^{-2}$
(But note: the use of the esu or Gaussian unit for electric displacement usually implies that the irrational displacement is being quoted, $D^{(\text{ir})} = 4\pi D$.)		
<i>Magnetic flux density, B (magnetic field)</i>		
tesla (SI unit)	T	$= \text{J A}^{-1} \text{ m}^{-2} = \text{V s m}^{-2} = \text{Wb m}^{-2}$
gauss (emu, Gau)	G	$= 10^{-4} \text{ T}$
au	$\hbar/ea_0^2$	$\approx 2.350\,52 \times 10^5 \text{ T}$
<i>Magnetic flux, φ</i>		
weber (SI unit)	Wb	$= \text{J A}^{-1} = \text{V s}$
maxwell (emu, Gau)	Mx	$= \text{G cm}^{-2} = 10^{-8} \text{ Wb}$
<i>Magnetic field, H (Volume) magnetization, M</i>		
SI unit	A m ⁻¹	$= \text{C s}^{-1} \text{ m}^{-1}$
oersted (emu, Gau)	Oe	$= 10^3 \text{ A m}^{-1}$
(But note: in practice the oersted, Oe, is only used as a unit for $H^{(\text{ir})} = 4\pi H$; thus when $H^{(\text{ir})} = 1 \text{ Oe}$, $H = (10^3/4\pi) \text{ A m}^{-1}$.)		

Name	Symbol	Relation to SI
<i>Magnetic dipole moment, m, μ</i>		
SI unit	A m^2	$= \text{J T}^{-1}$
emu, Gau	erg G^{-1}	$= 10 \text{ A cm}^2 = 10^{-3} \text{ J T}^{-1}$
Bohr magneton ^b	μ_{B}	$= e\hbar/2m_{\text{e}} \approx 9.274\,02 \times 10^{-24} \text{ J T}^{-1}$
au	$e\hbar/m_{\text{e}}$	$= 2\mu_{\text{B}} \approx 1.854\,80 \times 10^{-23} \text{ J T}^{-1}$
nuclear magneton	μ_{N}	$= (m_{\text{e}}/m_{\text{p}})\mu_{\text{B}} \approx 5.050\,79 \times 10^{-27} \text{ J T}^{-1}$
<i>Magnetizability, ξ</i>		
SI unit	J T^{-2}	$= \text{C}^2 \text{ m}^2 \text{ kg}^{-1}$
au	$e^2 a_0^2 / m_{\text{e}}$	$\approx 7.891\,04 \times 10^{-29} \text{ J T}^{-2}$
<i>Magnetic susceptibility, χ, κ</i>		
SI unit	1	
emu, Gau	1	
(But note: in practice susceptibilities quoted in the context of emu or Gaussian units are always values for $\chi^{(\text{ir})} = \chi/4\pi$; thus when $\chi^{(\text{ir})} = 10^{-6}$, $\chi = 4\pi \times 10^6$)		
<i>Molar magnetic susceptibility, χ^{m}</i>		
SI unit	$\text{m}^3 \text{ mol}^{-1}$	
emu, Gau	$\text{cm}^3 \text{ mol}^{-1}$	$= 10^{-6} \text{ cm}^3 \text{ mol}^{-1}$
(But note: in practice the units $\text{cm}^3 \text{ mol}^{-1}$ usually imply that the irrational molar susceptibility is being quoted, $\chi_{\text{m}}^{(\text{ir})} = \chi_{\text{m}}/4\pi$; for example if $\chi_{\text{m}}^{(\text{ir})} = -15 \times 10^{-6} \text{ cm}^3 \text{ mol}^{-1}$, which is often written as ‘ -15 cgs ppm ’, then $\chi_{\text{m}} = -1.88 \times 10^{-10} \text{ m}^3 \text{ mol}^{-1}$.)		

^aNote that the day is not exactly defined in terms of the second since so-called leap-seconds are added or subtracted from the day semiannually in order to keep the annual average occurrence of midnight at 24:00 on the clock.

^bThe year is not commensurable with the date and not a constant. Prior to 1967, when the atomic standard was introduced, the tropical year 1900 served as the basis for the definition of the second. For the epoch 1900.0, it amounted to $365.242\,198\,79 \text{ d} \approx 31\,556\,925.975 \text{ s}$ and it decreases by 0.530 seconds per century. The calendar years are exactly defined in terms of the day:

Julian year = 365.25 d

Gregorian year = 365.2425 d.

The definition in the table corresponds to the Gregorian year. This is an average based on a year of length 365 days, with leap years of 366 days; leap years are taken *either* when the year is divisible by 4 but is not divisible by 100, *or* when the year is divisible by 400.

^c1 N is approximately the force exerted by the earth upon an apple.

^d $T/^{\circ}\text{R} = (9/5)T/\text{K}$. Also, Celsius temperature θ is related to thermodynamic temperature T by the equation:

$$\theta/^{\circ}\text{C} = T/\text{K} - 273.15$$

Similarly Fahrenheit temperature θ_{F} is related to Celsius temperature θ by the equation:

$$\theta_{\text{F}}/^{\circ}\text{F} = (9/5)(\theta/^{\circ}\text{C}) + 32$$

^eThe name ‘amagat’ is unfortunately used as a unit for both molar volume and amount density. Its value is slightly different for different gases, reflecting the deviation from ideal behaviour for the gas being considered.

^fThe unit röntgen, employed to express exposure to X or γ radiations, is equal to: $\text{R} = 2.58 \times 10^{-4} \text{ C kg}^{-1}$.

^gThe units in quotation marks for electric potential through polarizability may be found in the literature, although they are strictly incorrect; they should be replaced in each case by the units given in the symbol column. Thus, for example, when a quadrupole moment is quoted in ‘ cm^2 ’, the correct unit is $e \text{ cm}^2$; and when a polarizability is quoted in ‘ $\text{\AA}^3$ ’, the correct unit is $4\pi\epsilon_0 \text{\AA}^3$.

^hThe Bohr magneton μ_{B} is sometimes denoted BM (or B.M.), but this is not recommended.

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